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THE EFFICIENCY OF A SHORT-TYPE REFRIGERATOR CAR

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INTRODUCTION

The successful transportation of fruits and vegetables over the long distances which separate the larger producing sections from the principal marketing points has been made possible by the refrigerator car, the development of which has taken place through a period of about 60 years. The first more or less successful attempt to refrigerate fruits in railroad cars was made in the late sixties.[1] From this beginning there has been evolved the refrigerator-car service which now extends over the railroads of the United States.

By far the greater part of the fruit and vegetable crops of this country moves by rail on a journey of such duration that control of transit conditions, especially temperature, is essential in order to prevent undue ripeness and deterioration through the development of decay or disease. This control is made possible by means of the refrigerator car, the insulated parts of which provide protection against heat and cold and also make it possible to effectively refrigerate the load by the use of ice.

The fundamental requirement of a refrigerator car is that it shall deliver its load at destination in a condition as nearly as possible the same as that in which it was received. It must carry a full load, but only so large as will permit its carriage to destination without damage or spoilage.

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[1] Weld, L. D. H. Private freight cars and American railways. 185 pp. 1908. (Columbia Univ., Faculty of Political Science.)

The cooling of a refrigerated shipment is dependent upon the circulation of air within the car. In accordance with a well-known principle of physics the cold air in the ice bunkers falls to the floor and passes out through openings at the bottom of the bulkhead into the loading space of the car. As the cold air absorbs heat from the lading it rises toward the ceiling and passes back to the bunkers through openings at the top of the bulkhead.

It is readily seen that under such conditions air circulation is necessarily slow and can be easily checked or retarded through faulty loading or car construction, in consequence of which the cooling of the load may be materially delayed. Up to the present time it has been found impracticable to install any mechanical means for accelerating the circulation of air in a refrigerator car. Therefore it is of primary importance that the load shall not be so great that provision can not be made for air channels through the load and the car. It has long been recognized that when too great a bulk is placed in a refrigerator car there is danger of deterioration of the load in the top layers.[2] Experienced shippers and receivers recognizing this fact guard against loading the produce too high in the cars; but unfortunately the minimum load requirements of railroads in some sections of the country are based on the number of packages, and too often this number is such that the shipper is forced to load too close to the top of the car in order to obtain the rates applicable to a minimum load.

Since the first attempts to refrigerate perishable products in railway transit, steady advance has been made in the construction of the refrigerator car; but it was not until early in 1918, during the life of the Railroad Administration, that any attempt was made to standardize its construction and design. Recommendations and specifications were then issued for the "United States standard refrigerator car." Because of the lack of standardization there have been in existence many types of cars, built more or less on the same basic principle but varying in dimensions, kind, and amount of insulation, etc. Most of these cars have been rebuilt and changed to conform as nearly as possible to the specifications for the United States standard car, but there are still some whose dimensions differ from those recommended.

The difference in dimensions, which is generally in the inside length between bulkheads, has brought about more or less dissension between shippers, railroads, and refrigerator-car lines that are operating cars varying from the standard. The standard inside dimension between bulkheads, 33 feet 2¾ inches, has an important practical bearing when loading is considered. Those accustomed to loading the standard-length car encounter difficulty when a short car is placed at the loading point, in that it is necessary to resort to some expedient in order to place the required minimum load in the car.

The shippers of fruits and vegetables have manifested to a marked degree their dissatisfaction with a refrigerator car of certain dimensions supplied them. It is known as the "short car," owing to the fact that it is slightly more than 3 feet shorter than the length recommended by the United States standard specifications.

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[2] Cooper, M. Practical cold storage. Ed. 2, p. 429. Chicago. 1914.

Whether these complaints are justified or merely based on prejudice seemed to be a matter that could be settled only by a thorough and impartial investigation by some disinterested organization. Such an investigation has been conducted by the United States Department of Agriculture with the cooperation of the growers, the railroads, the refrigerator-car lines, and the receivers. The facilities of the railroads and car lines were placed at the disposal of the investigators, and the shippers permitted them to load and handle the commodity in any way they preferred.

Before making an actual test of the equipment under discussion it was thought necessary to secure the opinion of those interested at market destinations; several of the larger receivers were interviewed. The result showed that the greatest opposition was based not so much on the carrying qualities of the cars in question as on the minimum-load requirements of the originating lines. Since much of the dissatisfaction seemed to originate in relation to the movement of celery, this crop was selected for handling in these investigations. The minimum-load requirements are 350 crates per car on a 50-pound crate basis. The receivers claimed that only 294 crates could be loaded into the short cars with reasonable certainty that the commodity would arrive in good condition, and in their opinion this number of crates would be a safe load. They also asserted that the requirement of a minimum of 350 crates for this type of car inflicts a penalty on the shipper, in that he must pay the carrier for a load of 350 crates when he can place only 294 crates with safety in the car.

Interviews with the shippers brought out the fact that they were of the same opinion with reference to the minimum-load requirements, but they expressed the belief that the small ice bunkers with which these cars are equipped are not capable of supplying the necessary amount of refrigeration.

The general opinion among the shippers and receivers can best be expressed by the statement that they consider the 294-crate load all that this type of car will carry and refrigerate satisfactorily. This does not imply that 350 crates of celery can not be put into the car, but that such a load necessitates the placing of four layers in the car instead of the customary three layers, which is considered the maximum height for celery loading. They also contend that loads more than three layers high will not carry well and that the commodity in the higher layers deteriorates in transit and arrives at destination in bad condition.

In order to test the performance of these short cars it was decided that accurate temperature readings must be made. Celery was used in these tests, not only because it appeared to be the main source of grievance of the shippers but also because it packs tightly in crates, loads rather tightly, and generally is hard to refrigerate. In other words, it was thought that the performance of these cars in the movement of celery would be an index of what might be expected with other commodities loaded and handled under the same conditions. The cars were taken directly out of road service and the usual commercial practices were followed in preparing them for this series of tests; that is, no preparation of the cars was made other than that commonly given in the regular service afforded the shippers. They were cleaned in the usual way, given the regular inspection, preiced and reiced in the customary manner, and all through the series of tests were given the service generally afforded shippers by the refrigerator-car lines and the railroads.

In order to make a fair and conclusive test of the equipment, it was decided that the operations should be conducted at the end of the Florida celery-shipping season, as it was believed that a combination of climatic conditions would then be encountered that would not only put the cars to a rigid test but would furnish enough evidence on which to base a definite conclusion as to their efficiency.

A series of three tests was made, the first beginning on March 27 and ending March 31, the second beginning April 9 and ending April 13, and the third beginning April 23 and ending April 30, 1924. In each of the three tests four cars of the same general characteristics were used, as follows:

- Insulation:
  - Floor, 2 inches.
  - Sides, 2 inches.
  - Ends, except bulkhead, 2 inches.
  - Roof, 2 inches.
- Well-fender height: 2 inches at A end, 4 inches at B end.
- Bulkhead top opening, 12 inches.
- Bulkhead bottom opening, 12 inches.
- Length between bulkheads, 29 feet 10⅝ inches.
- Type of ice bunker, suspended basket.
- Ice-bunker capacity, 6,800 pounds.
- Floor racks, strips.

It will be noted that the cars in this series have 2 inches of insulation in the floor, sides, ends, and roof; that the bulkhead is not insulated; and that the ice bunkers are of the suspended-basket type, having a capacity of 6,800 pounds. They are not equipped with floor racks but have stripping along the floor which raises the load about 1 inch. With the exception of a slight variation in the size of the bulkhead openings, there is no difference in the construction of the cars.

FIRST TEST

The cars selected for the original test were preiced to full capacity at Sanford, Fla., on the evening of March 26, 1924, and were spotted for loading on the following morning. They were loaded the same day and reiced during the early morning hours of March 28, when the trip to Philadelphia and New York began.

In this test car A was loaded with 294 crates, car B with 315 crates, and cars D and E with 350 crates each. Car C was omitted, since in the tests the car thus designated carried a 336-crate load, and there was no such load in the first test. The 294 crates in car A were loaded 3 layers high and 7 rows wide and 14 stacks, and the 315 crates in car B were loaded 3 layers high and 7 rows wide and 15 stacks.[3] In order to put 15 stacks in the car it was necessary to place the crates at the bunkers on end. Since the crates are 20 by 24 inches it was found necessary to load two of the stacks on the 20-inch side, whereas with the 294 load all crates were placed on the 24-inch side, or right side up. The 294 load necessitated stripping, placed vertically, in order to take up the few inches of space between the stacks and prevent the shifting of the load. To place 350 crates in the car, as was done in cars D and E, the same method of loading was followed as for the 315 load, but 35 crates had to be laid flat on the third layer. In the 350 load it was impossible to stand the top crates upright, which should be done, since there was a space of only approximately 18 inches between the top of the third layer (top of the load) and the ceiling of the car. Sometimes this space is even less, especially when the large type of celery is loaded, as the stalks then protrude through the top of the crate and take up more space between the layers. With the crates laid flat there was a space of only 8 to 10 inches between the top of the fourth layer and the car ceiling.

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[3] Reference is made to "layers," "stacks," and "rows" of packages. These terms have been adopted in place of the indefinite designation "tier." A layer is a horizontal course or stratum of the load in a car one package high. A stack is a pile of packages one package in length extending across the car. A row is a pile of packages one package wide extending lengthwise from end to end of the car.

The cars were equipped with electrical-resistance thermometers placed in the center of several packages as they were loaded in the cars. The positions of these test packages, shown in Table 1, were the same in all cars with the exception of those loaded with 350 crates. In these cars an additional thermometer was placed in the same position at the bunker, quarter length, and doorway in the fourth or top layer.

TABLE 1.—*Positions of test packages of celery in refrigerator cars loaded at Sanford, Fla., in 1924*

Layer	Bunker	Quarter length [1]	Doorway
Third	Fourth row (top)	Fourth row (top)	Fourth row (top).
Second	Fourth row (middle)	Fourth row (middle)	Fourth row (middle).
First	Fourth row (bottom)	Fourth row (bottom)	Fourth row (bottom).

[1] The quarter length is a point midway between the doorway and the bunker bulkheads.

As the cars were loaded the crates were placed in the positions specified in Table 1 and marked with a symbol which identified them for inspection at the time of unloading. The temperatures in these marked crates were determined with the resistance-thermometer equipment.

The cars were closed immediately after loading, the outside temperature at this time being 76° F. The loading data for all cars are shown in Table 2.

TABLE 2.—*Loading data for all refrigerator cars loaded with celery used in test No. 1 at Sanford, Fla., in 1924*

Celery load	Loading		Average temperature of celery when loaded
	Begun	Completed	
			°*F.*
Car A	2.45 p. m	6.00 p. m	74
Car B	8.50 a. m	12.15 p. m	70
Car D	11.50 a. m	4.30 p. m	74
Car E	9.00 a. m	2.45 p. m	70

All stock loaded in the cars was known as field run; that is, no attempt was made to fill the cars with a solid load of a certain size. The celery was graded, packed, and loaded immediately after digging.

When loaded, all cars were assembled at the Sanford icing station and reiced to capacity. They left Sanford at 3.15 a. m. on March 28 and arrived at their destinations on March 30. Car B was diverted at Potomac Yards, Va., to Philadelphia, arriving there at 10 p. m. March 30, and it was unloaded the next day. The other cars proceeded to New York, where cars A and E were unloaded on March 31 at 8.45 p. m. Car D was returned to Jersey City and there unloaded for storage on the afternoon of April 1. All cars moved under standard refrigeration and were reiced at the regular icing stations en route. The icing record for the cars is shown in Table 3.

TABLE 3.—*Icing record of the four refrigerator cars in test No. 1, loaded with celery, Sanford, Fla., to New York, in 1924*

[On arrival the bunkers of cars A and D were two-thirds full, of car B three-fourths full, and of car E two-thirds full at the B end and three-fourths full at the A end]

Place	Date	Time	Ice supplied (pounds)			
			Car A	Car B	Car D	Car E
Sanford, Fla	Mar. 26	8.10 to 8.45 p. m	6,800	6,800	6,800	6,800
Do	Mar. 28	1.25 to 1.40 a. m	3,000	2,800	2,800	3,400
Jacksonville, Fla	do	11.35 to 11.50 a. m	1,200	800	1,400	1,200
Bennett, S. C	Mar. 29	8.40 to 8.50 a. m	4,500	3,600	4,800	4,200
Rocky Mount, N. C	Mar. 30	12.40 to 12.55 a. m	1,400	1,000	1,400	1,200
Potomac Yards, Va	do	1.10 p. m	1,300	1,100	1,400	1,800
Total			18,200	16,100	18,600	18,600

On arrival at destination the shipments were inspected. The results of these inspections will be considered later.

TEMPERATURES MAINTAINED

During the course of the trip from points of origin to destinations, readings were made of the temperatures within the cars at the various positions previously mentioned. Some of these temperatures are shown graphically in the accompanying diagrams. (Figs. 1 to 5.)

Since all the cars used in the tests were of the same type, they will be referred to by letter and load only, in order to simplify the discussion of the temperatures maintained within them, car A having a load of 294 crates, car B 315 crates, and cars D and E 350 crates each. With the exception of those showing the outside air temperatures, the curves in diagrams refer to the temperature of the celery and not to the air within the car.

It will be noted by referring to Figure 1 that the 294 load (car A) did not cool down as rapidly in the bottom-bunker position as the 315 and 350 loads (cars B and D), but maintained a decline in temperature approximately parallel to that in car B until about 24 hours after loading, when car E became 3 degrees F. cooler than car A. Car A at no time throughout the trip became as cold in the bottom-bunker position as either of the other cars, cars B and D being about equal.

Figure 2 shows the temperature at the top of the bunker. In this case there is a very marked difference between the temperatures maintained in car A and those in the other cars, the average being approximately 12 degrees F. Car B shows an average temperature 5 degrees higher than car A. Car D shows an average of 15 degrees and car E 12 degrees higher than car A. It will be noted that in all cases, with the exception of car A, from the time of loading until 24 hours afterwards, there is a rise of several degrees in temperature. Car A shows a rise of only 2 degrees above the initial loading temperature. After a period of approximately two hours a rapid drop is shown in this car, while in the other cars a very slow decline is noted after about 24 hours.

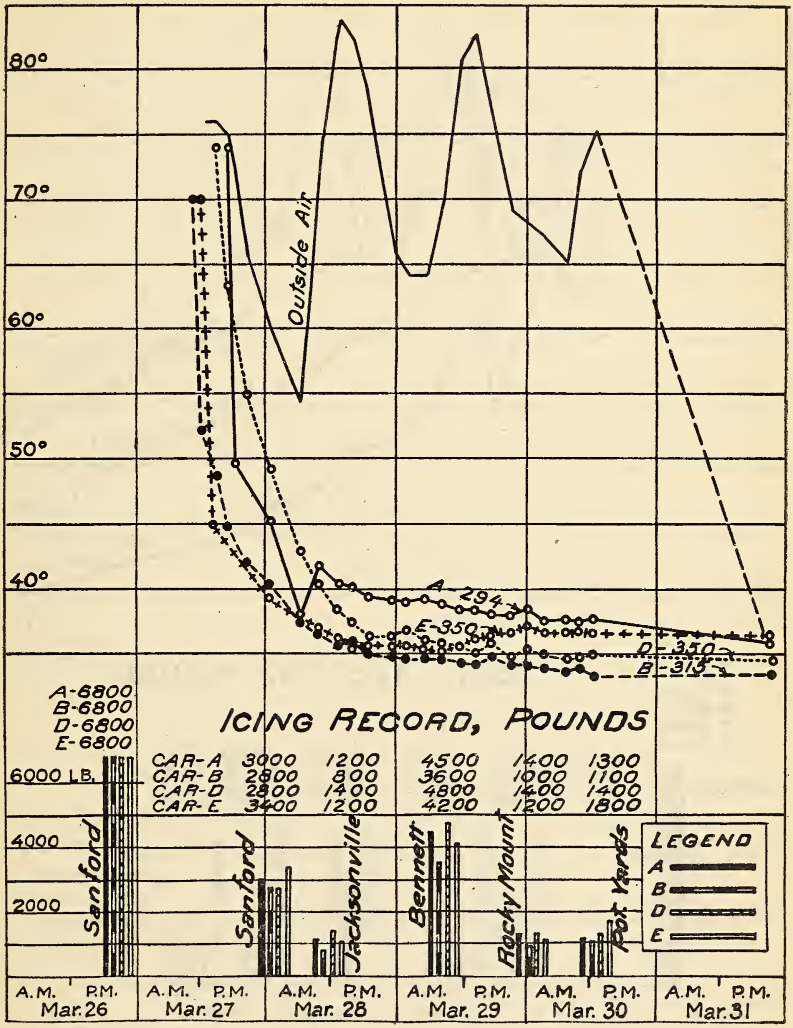

FIG. 1.—Diagram showing the bottom-layer temperatures of celery at the bunker in all cars in the first trip from Sanford, Fla., to New York, March 27 to 31, 1924. Car A was loaded with 294 crates, car B with 315 crates, and cars D and E with 350 crates each

According to the usual practice of the shippers, the cars were loaded as rapidly as possible and the doors closed, thus confining within the car all the heat given off by the lading. The temperature of the celery at the time of loading in the four cars averaged 72° F. in this test. (Table 2.) It is necessary that a car cool its contents rapidly after loading, and it is evident that the ice in the bunkers at either end of the heavily loaded cars did not cool the lading to a safe temperature in a 24-hour period. It was shown in the lighter load that there was undoubtedly a quicker cooling action

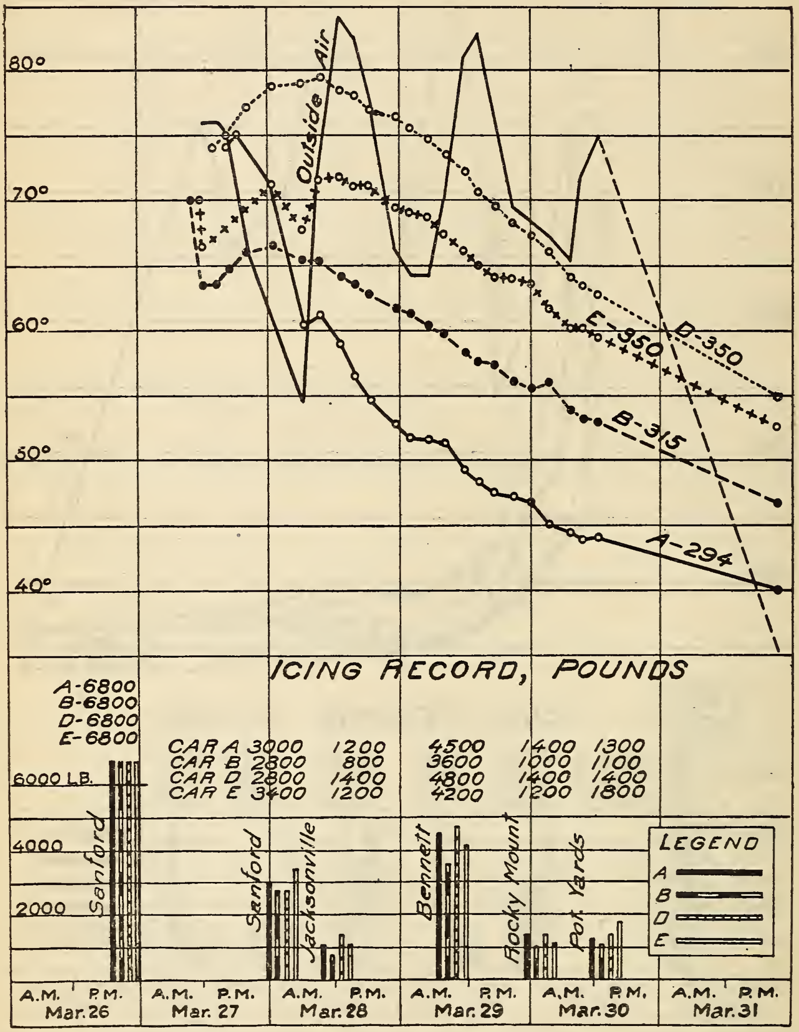

FIG. 2.—Diagram showing the top-layer temperatures of celery at the bunker in all cars in the first trip from Sanford, Fla., to New York, March 27 to 31, 1924. Car A was loaded with 294 crates, car B with 315 crates, and cars C and D with 350 crates each

in this particular position than in the heavy loads. When the temperature of the commodity at loading time is taken into consideration it is manifest that in heavily loaded cars it can be brought down only very slowly, particularly in the top of the load. The crates of celery are generally placed an inch or two apart to facilitate the circulation of air, which has a tendency to equalize the rate of cooling throughout the load.

By contrasting Figures 1 and 2 a great difference in temperature between the top and the bottom of the load will be seen, brought about by the heavier cold air settling in the lower part of the car and the entire lower layer cooling off rather quickly, although the temperatures did not indicate as rapid cooling in the center of this layer or at the doorway as near the bunkers. This slower cooling of the upper layers, especially the top layer, was particularly noticeable in the cars after they had been loaded and closed for a few hours. When the doors in cars loaded in the same manner as were those in the tests are opened, the air at the floor feels cold, but that near the ceiling is frequently hot. This heat sometimes causes serious damage by turning the leaves of the celery a light yellow, which injures its appearance and is regarded on the market as an indication of lessened vitality. Crates containing celery with yellow tops are discounted in price accordingly. It is naturally more difficult to lower the temperature in a car which is loaded to within 8 or 10 inches of the ceiling than where more space is left between the ceiling and the top of the load. This is clearly illustrated in Figure 2, where car D, loaded with 350 crates, shows a marked increase in temperature over car A with its 294 load, which shows a marked decrease. The same is true where the top positions at the doorway are considered. The 350 loads show a marked increase in temperature as compared with the 294 loads.

The temperatures of the second layer at the quarter length in cars D and E proved to be lower at the end of the trip than in car A. The cooling of cars B and E was about equal, even though car E was loaded at a lower temperature and three hours before car D. However, after the first 24 hours car E showed a temperature about 2 degrees higher than car D and maintained it throughout the trip. Car A showed a temperature fall parallel with cars B and E, but throughout the trip maintained an average temperature approximately 3 degrees higher than car D.

Car B with its 315 load showed a considerably higher temperature than either of the other cars, averaging approximately 4 degrees higher than car A and 8 degrees higher than car D.

To determine what effect the placing of an additional layer would have on the third layer, the temperatures of the third layers in all cars were compared. It will be remembered that in cars A and B the third layer was the top of the load, while in cars D and E the fourth was the top layer. Cars A and B showed a decided drop in temperature in the top, or third layer, positions, while cars D and E showed a marked rise. It is therefore evident that the placing of a fourth layer has some effect on the temperature of the layer directly below it.

The average temperatures of the top layers, as shown in Figure 3, indicate that cars D and E, while paralleling each other with car D

3 degrees higher than car E, are higher than cars A and B by about 10 degrees, and that car B averages about 2 degrees higher than car A, while car A maintains the lowest temperature of all and shows a rapid decline.

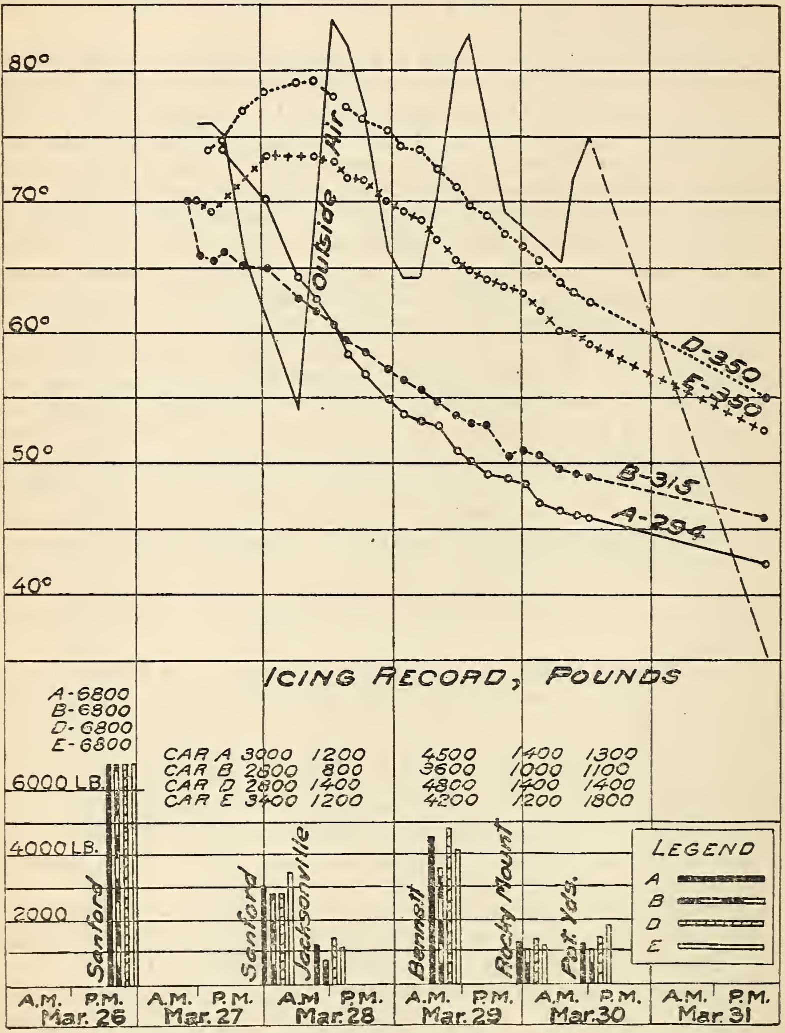

FIG. 3.—Diagram showing the average top-layer temperatues of celery in four cars in the first trip from Sanford, Fla., to New York, March 27 to 31, 1924. Car A was loaded with 294 crates, car B with 315 crates, and cars D and E with 350 crates each

The average temperature of the bottom layers (fig. 4) indicates that there is but little difference in the temperatures of the loads in this position. Car A shows a faster cooling at the beginning of the test than either of the other cars, but after the end of the second day maintains a comparatively steady temperature, paralleling car E but maintaining a temperature about 1 degree higher. Although there is an actual difference in temperature of about 2½ degrees between the bottom layers of cars D and A and 1 degree between cars B and D, these differences are not nearly so marked or so important from the standpoint of the general condition of the lading as that found in the temperatures of the top layers of the same cars.

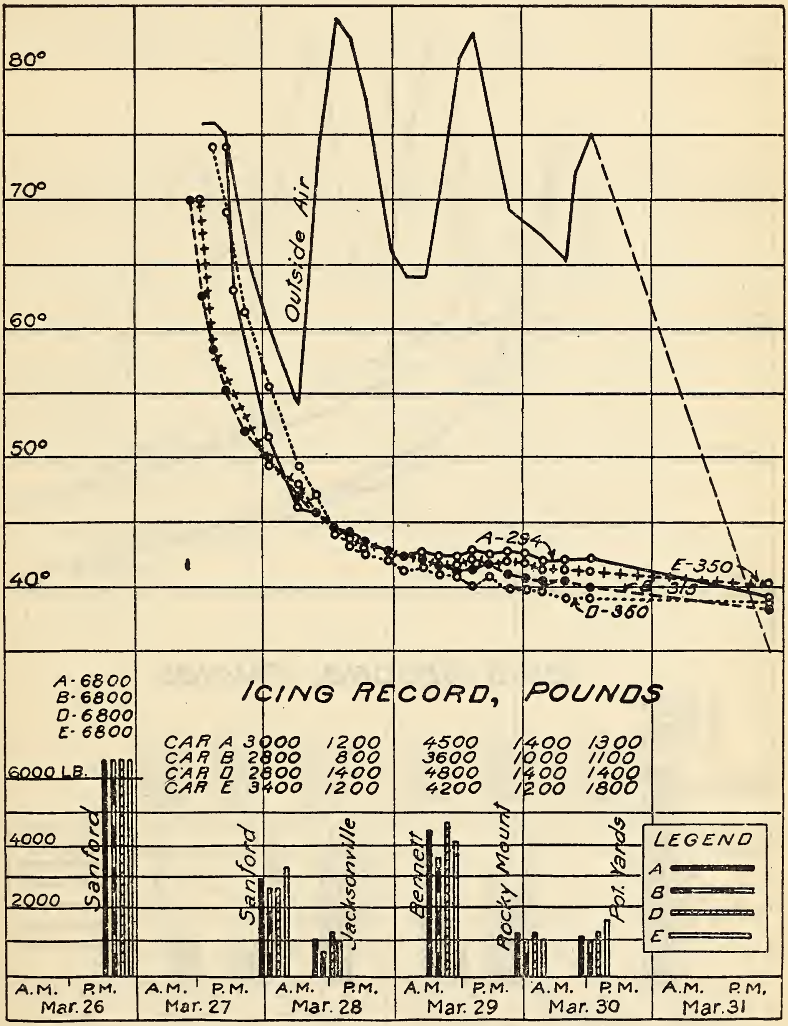

FIG. 4.—Diagram showing the average bottom-layer temperatures of celery in four cars in the first trip from Sanford, Fla., to New York, March 27 to 31, 1924. Car A was loaded with 294 crates, car B with 315 crates, and cars D and E with 350 crates each

The average temperatures at all locations in the loads clearly indicate that there is a distinct similarity between cars A and B and between cars D and E, which may be noted by referring to Figure 5.

By comparing the temperature records shown in Figures 1 to 5 with the results of the inspections made at market destinations (Tables 8, 9, and 10) it is apparent that there is a relation between the yellowing at the top of the load and the temperatures maintained.

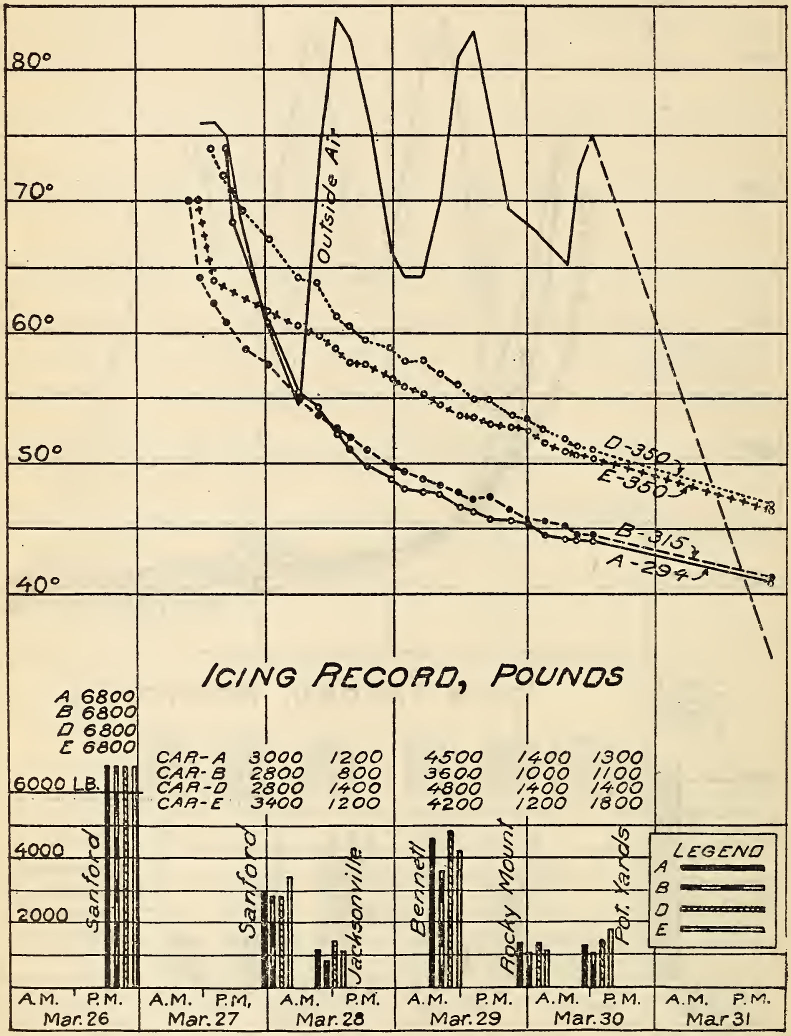

FIG. 5.—Diagram showing the average car temperatures of celery in four cars in the first trip from Sanford, Fla., to New York, March 27 to 31, 1924. Car A was loaded with 294 crates, car B with 315 crates, and cars D and E with 350 crates each

It would also seem that the four cars under consideration bring down the temperature as rapidly as can be expected and are efficient in cooling the load. The marked rise in temperature of the commodity in the tops of the cars directly after loading is probably caused by the natural heating of the produce before the ice is effective and is augmented by the additional heat contained in the produce in the fourth layer. The cooling effect is further delayed by the heavier lading and reduced air circulation of the heavier loaded car. At the same time it must be understood that placing this fourth layer in the car brings the top of the load within the zone of heated air, which naturally rises to the top of the car.

From the results obtained in this test it would seem that the 294 or 315 load is preferable for loading these short cars.

SECOND TEST

Four cars were again selected and the second test run under exactly the same conditions as the first except that the celery was becoming more mature and the weather conditions promised to be warmer.

In the previous test loads of 294, 315, and 350 crates were placed in the cars. In order to get as many in the car as possible without loading a fourth layer, in this test 336 crates were tried, making four types of loads. The method of loading in all cases was the same as in the first test with the exception of car C, which was loaded with 336 crates, 8 rows wide, 3 layers high, and 14 stacks to the car. This arrangement did not allow for any space between the crates, but made a solid, compact mass. The loading data for the cars used in this test are shown in Table 4.

TABLE 4.—*Loading data for all refrigerator cars loaded with celery used in test No. 2 at Sanford, Fla., in 1924*

Celery load	Loading		Average temperature of celery when loaded
	Begun	Completed	
			° F.
Car A	11.30 a. m.	2.30 p. m.	73.5
Car B	3.30 p. m.	5.45 p. m.	73.5
Car C	9.00 a. m.	11.15 a. m.	67.0
Car D	9.50 a. m.	2.30 p. m.	71.0

After the cars were loaded they were reiced to capacity and left Sanford on April 9 for New York. (Table 5.)

TABLE 5.—*Icing records of the four refrigerator cars loaded with celery in test No. 2, Sanford, Fla., to New York, in 1924*

[On arrival at Pier 29, New York City, the bunkers of all cars were five-sixths full]

Place	Date	Time	Ice supplied (pounds)			
			Car A	Car B	Car C	Car D
Sanford, Fla.	Apr. 8	4.45 to 5.15 p. m.	6,800	6,800	6,800	6,800
Do.	Apr. 9	7.00 to 7.40 p. m.	2,000	1,000	1,400	1,600
Jacksonville, Fla.	Apr. 10	8.20 to 8.24 a. m.	1,400	1,600	1,000	1,400
Bennett, S. C.	Apr. 11	7.40 to 7.52 a. m.	2,700	2,700	2,700	2,700
Rocky Mount, N. C.	Apr. 12	3.00 a. m.	1,400	1,600	1,600	1,600
Potomac Yards, Va.	do.	3.45 p. m.	1,050	800	1,000	850
Total			15,350	14,500	14,500	14,950

TEMPERATURES MAINTAINED

The temperatures maintained in this test were obtained in the same manner as in the previous test, and in comparing them with those of the first test very little difference was noted. The temperatures at the bottom-bunker positions were practically the same, car B maintaining the lowest temperature, the test crates being in the same relative positions as in the first test. However, the outside air was considerably colder than during the first test, which accounts for the slight difference of about 3 degrees in temperature.

After the first 48 hours the temperature in the bottom-bunker positions in all cars in this test, as in the first one, indicated that car C with its 336-crate load maintained a slightly lower temperature than car A with its 294-crate load. Car A, however, was loaded at a temperature of 73.5° F. and car C at a temperature of 67° F. There is a remarkable parallel in the temperatures in these two cars, an average difference of 4 degrees being maintained throughout the test. Cars B and D had the same loads as cars B and D in the first test and bear the same relative rating when the temperatures maintained by them are compared.

Figure 6, illustrating the temperatures in the bottom layers of the loads at the doorway, shows that car C maintained a considerably higher temperature in this position than any of the other cars, there being very little difference between cars D and A. Car B shows an average temperature about 2 degrees lower than either cars D or A and after noon of the first day a difference of 9 degrees lower than car C. As in the first test, the temperature of the 315-crate load in the bottom layer at the doorway is the lowest, being approximately 4 degrees lower at the end of the trip than that of the car containing the 350-crate load and 2 degrees lower than the 294-crate load.

By referring to the outside-air curves in Figure 6 it will be noted that from 6 p. m. on April 10, when the outside temperature registered 86° F., the temperature continued to drop rapidly until about 10 a. m. on April 12, when it reached 30° F., and from that time rose rapidly. Although there is no perceptible fluctuation in the temperatures within the cars, it will be noted that the ice consumption of these cars was considerably affected. It is therefore reasonable to suppose that the slowly falling temperature of the commodity within the car may have been influenced to some degree by the outside weather conditions.

Referring to Figure 7, the same conditions in temperature in the different types of loads can be noted as in the first test. The same rise in temperature in the 350-crate load (car D) occurred immediately after the closing of the car door. The same general decline for the lighter loads (cars A and B) is also to be noted in the curves shown in Figure 7. There was a slight rise in car C, but the same general relation in temperature conditions is maintained throughout at this position, i. e., the top at the door.

After averaging the temperature for the third layer it was found that between the light and heavy loads there was a difference of 4 degrees throughout the trip. Car C with the 336-crate load fluctuated between the temperatures maintained by cars A and B, while car D showed a higher temperature than any other car by approximately 2 degrees. Car A in the first test maintained a cooler temperature than in the second, yet the heavy load maintained relatively the same temperature during both tests as the 315-crate load. The average lower temperatures in this test fell within the same range

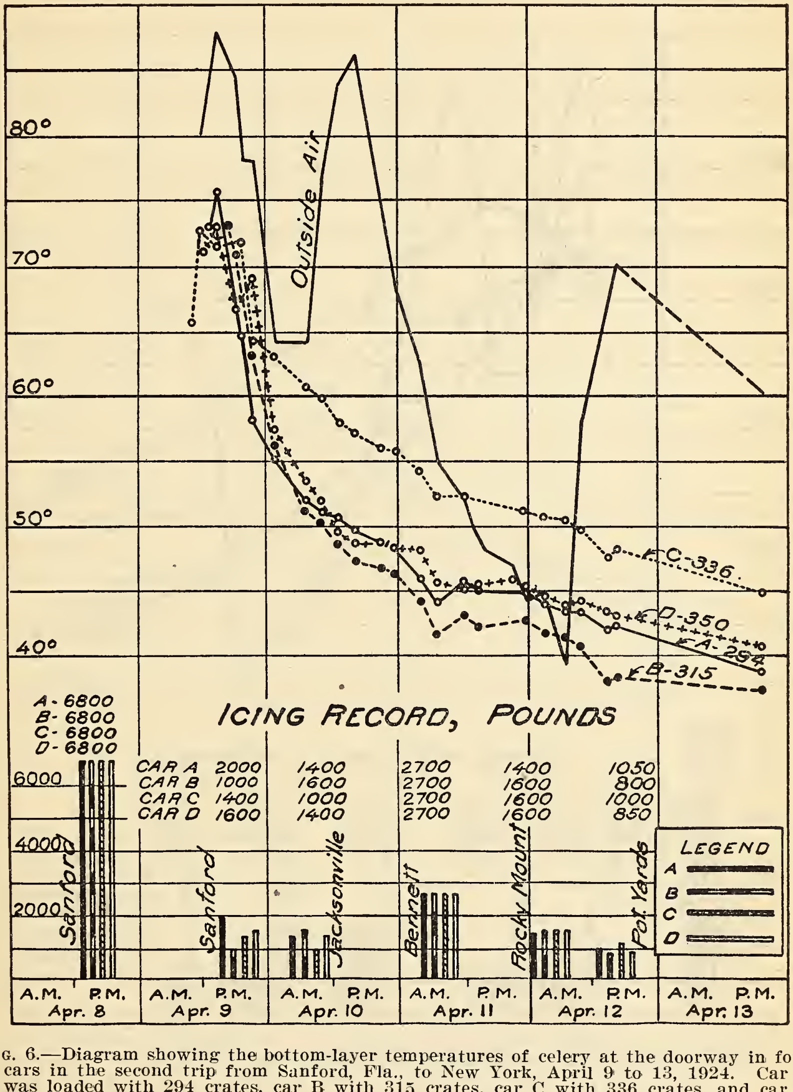

FIG. 6.—Diagram showing the bottom-layer temperatures of celery at the doorway in four cars in the second trip from Sanford, Fla., to New York, April 9 to 13, 1924. Car A was loaded with 294 crates, car B with 315 crates, car C with 336 crates, and car D with 350 crates

as those established in the first, and the temperatures generally maintained with the relative loads were practically the same, car A having the coldest and car D the warmest load. Car B averaged 2 degrees warmer than car A throughout the test, and car C averaged between cars D and B. Car D maintained throughout the test a difference approximating 10 degrees higher than cars A and B. A comparison of the average bottom layers showed that the difference in temperature was so slight as to be negligible when the loading and outside-air temperatures were taken into consideration, and that it would have little effect on the commodity carried within these cars.

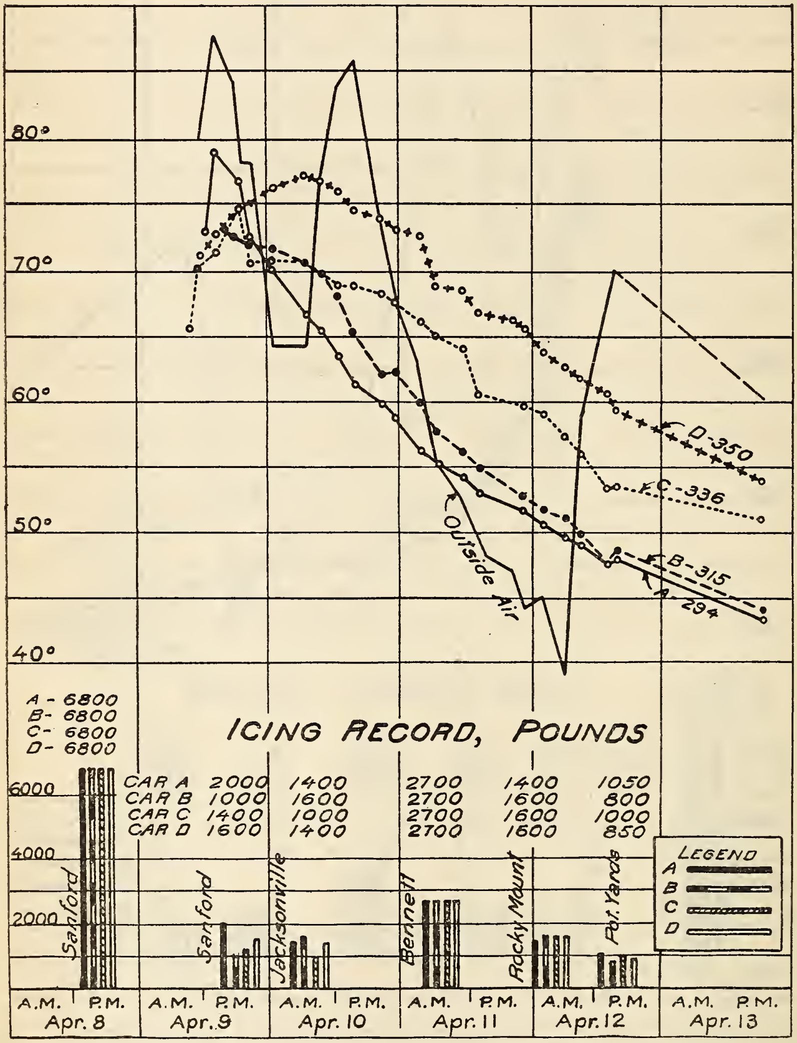

FIG. 7.—Diagram showing the top-layer temperatures of celery at the doorway in four cars in the second trip from Sanford, Fla., to New York, April 9 to 13, 1924. Car A was loaded with 294 crates, car B with 315 crates, car C with 336 crates, and car D with 350 crates

Figure 8 shows the average temperatures maintained throughout the cars. It will be noted that cars A, B, C, and D maintained temperatures in the same relative order, car A being the coldest and car D the warmest, all falling practically within the range established during the first trip. From this it would seem that so far as temperature conditions are concerned the lighter load has the advantage over all loads carried on the second trip.

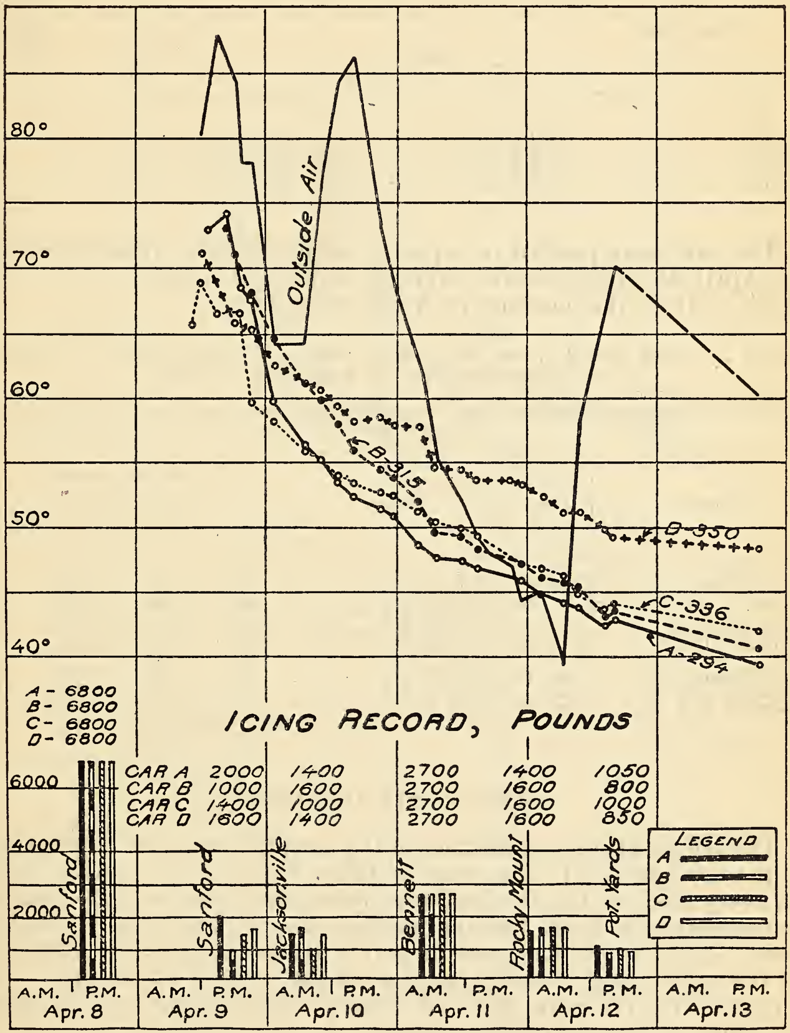

FIG. 8.—Diagram showing the average car temperatures of celery in four cars in the second trip from Sanford, Fla., to New York, April 9 to 13, 1924. Car A was loaded with 294 crates, car B with 315 crates, car C with 336 crates, and car D with 350 crates

THIRD TEST

This test was run in exactly the same manner as the two preceding tests, the only difference being that the celery used was somewhat older and the outside air warmer. There was a slight difference in the temperature of the celery at loading, as will be noted in Table 6, which shows the loading data for the third and last test.

TABLE 6.—*Loading data for all refrigerator cars loaded with celery used in test No. 3 at Sanford, Fla., in 1924*

Celery load	Loading		Average temperature of celery when loaded
	Begun	Completed	
			° *F.*
Car A	11.00 a. m.	2.25 p. m.	73
Car B	9.20 a. m.	4.25 p. m.	74
Car C	2.30 p. m.	5.00 p. m.	72.5
Car D	9.15 a. m.	11.35 a. m.	70

The cars were preiced to capacity at Sanford on April 23, loaded on April 24, reiced on the evening of that day, and left for New York early on the morning of April 25. (Table 7.)

TABLE 7.—*Icing record of the four refrigerator cars loaded with celery in test No. 3, Sanford, Fla., to New York, in 1924*

[On arrival at destination the bunkers of car A were seven-eighths full, whereas those of the other cars were thirteen-sixteenths full]

Place	Date	Time	Ice supplied (pounds)			
			Car A	Car B	Car C	Car D
Sanford, Fla.	Apr. 23	6.15 p. m.	6,800	6,800	6,800	6,800
Do.	Apr. 24	7.20 to 7.35 p. m. 11.23 to 11.25 p. m.	1,800	3,200	1,200	2,000
Jacksonville, Fla.	Apr. 25	10 to 10.15 a. m.	2,600	1,200	2,400	1,600
Bennett, S. C.	Apr. 26	12 midnight to 12.25 a. m.	2,100	2,700	2,700	2,700
Rocky Mount, N. C.	Apr. 27	5.05 to 5.35 a. m.	800	1,200	1,200	1,200
Potomac Yards, Va.	do.	7.21 to 7.35 p. m.	800	1,000	700	600
Greenville, N. J.	Apr. 28	12.56 a. m.			1,200	
Total			14,900	16,100	16,200	14,900

TEMPERATURES MAINTAINED

The temperatures maintained in the lading of the cars on the third trip were practically the same as those shown in the earlier trips. In every position in the cars the temperatures bore the same relation to each other as those for like positions on the first trip. However, car C with the 336 load maintained a higher temperature than any of the other cars, probably because of the method of loading. The temperatures taken in this test were practically the same as those obtained in the two previous tests.

To appreciate fully the efficiency of any type of equipment and arrive at a definite conclusion as to its efficiency it is necessary to make more than one study of its performance. The average rather than the individual performance should be the guiding factor. In the three tests conducted 12 cars of the same type with four types of loads were used. The average temperatures maintained by these cars with their various loads are shown in Figures 9, 10, and 11. As shown in the foregoing charts, the similarity of the temperatures maintained under slightly varying weather conditions is striking.

However, it is noted that the temperatures throughout the entire series of tests varied according to the load within the car, the lighter load maintaining a generally lower temperature than the heavier one.

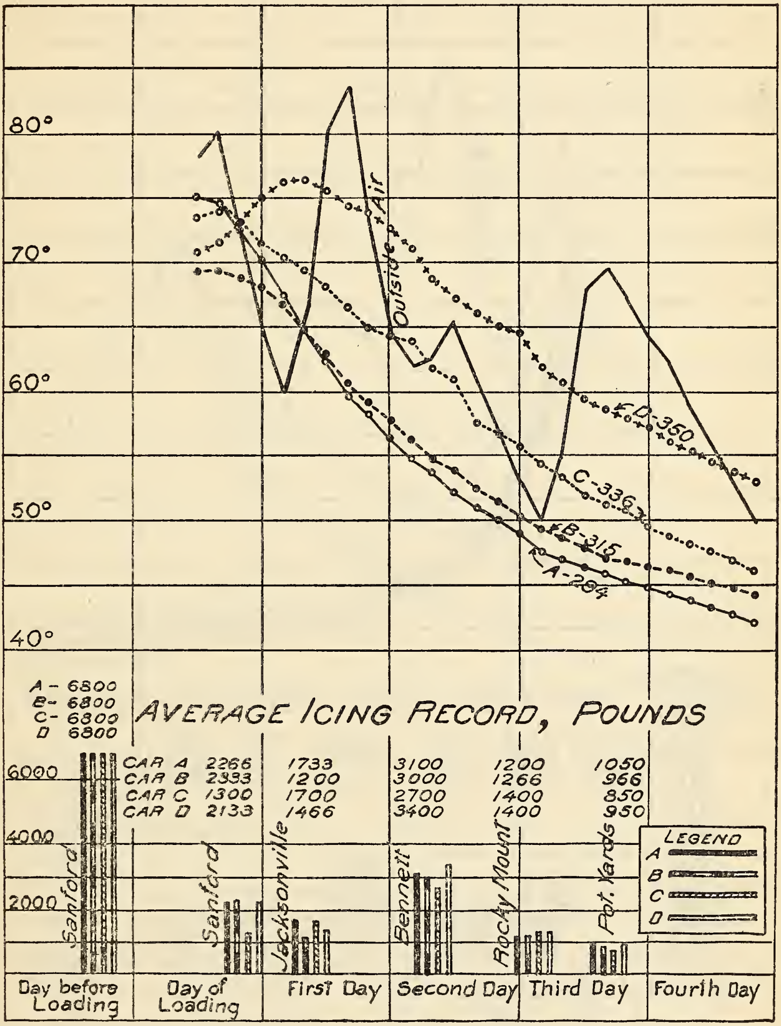

FIG. 9.—Diagram showing the average top-layer temperatures of celery in all loads except car E, which was a duplicate of car D, in three trips from Sanford, Fla., to New York. Cars A were loaded with 294 crates each, cars B with 315 crates each, cars C with 336 crates each, and cars D with 350 crates each

Figure 9 illustrates the average top-layer temperatures of all loads. Here it is seen that throughout the three tests the average top-layer temperature of the 350 load is 14 degrees higher than that for car A, whereas car C is 7 degrees and car B 2 degrees higher than car A.

The average bottom-layer temperatures of all loads (fig. 10) show but slight variation. For all practical purposes they may be considered the same with the exception of car C, where, again, this difference is undoubtedly brought about through the method of loading. Although these temperatures may be considered uniform, yet car A is higher than either car C or car B. The temperatures maintained by the cars in which the 294 load was placed are also affected by the method of loading, which allows for adequate air circulation and brings the load down out of the zone of heated air which is found above the third layer.

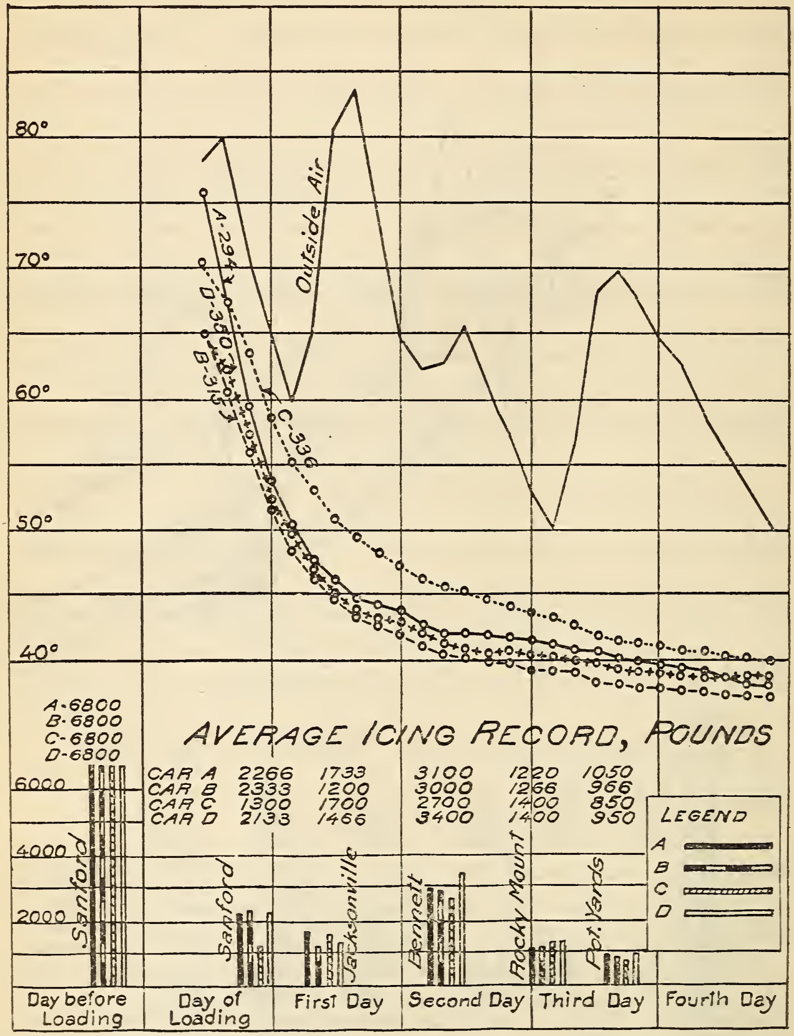

FIG. 10.—Diagram showing the average bottom-layer temperatures of celery in all loads except car E, which is a duplicate of car D, in three trips from Sanford, Fla., to New York. Cars A were loaded with 294 crates each, cars B with 315 crates each, cars C with 336 crates each, and cars D with 350 crates each

CONDITION OF CELERY ON ARRIVAL AT DESTINATIONS

Tables 8, 9, and 10 show the results of the inspections made at market destinations of the test crates which were placed in different positions in the cars. While making these inspections it was noticed that the celery was considerably shaken down and jammed in the crates that had been loaded on their sides in the 315 and 336 loads in order to place that number of crates in the car without the addition of a fourth layer, leaving a vacant space averaging about 3

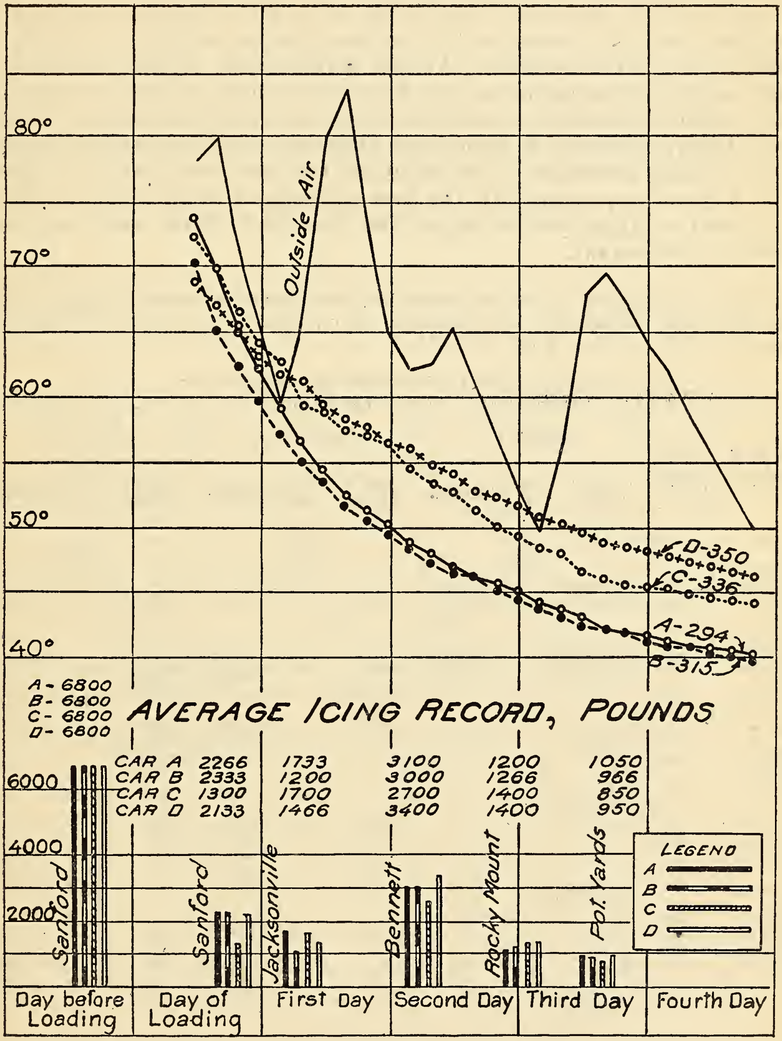

FIG. 11.—Diagram showing the average temperatures of celery in all cars except E, which was a duplicate of car D, in the three trips from Sanford, Fla., to New York, March 27 to April 30, 1924. Cars A were loaded with 294 crates each, cars B with 315 crates each, cars C with 336 crates each, and cars D with 350 crates each

inches between the celery and the side of the crate. This gave the impression of a slack-packed crate; instead, the celery had been so jammed in the crate through the jarring it had received that bruising and cutting had resulted.

Table 8 shows the condition of the celery in the test crates placed at the bunker adjacent to the bulkhead in each of the three tests.[4] A study of this table will show that, with the exception of those in the first test, all crates at the bottom-bunker positions arrived at market in good condition. At the termination of the first test a very slight yellowing is recorded for the crates in this position in cars A and E. In the second layer the same condition exists. In the third layer, however, a somewhat different situation will be noted. The 294 load recorded a yellowing in the first test, but is credited with a green appearance in the two subsequent tests. The 315 load developed a slight yellowing in the first and third tests, but was green in the second.

TABLE 8.—*Inspection record on arrival at destinations of crates of celery placed at the bunker adjacent to the bulkhead in refrigerator cars used in three tests, Sanford, Fla., to New York, in 1924*

[Car D was diverted at Philadelphia and inspected there]

Layer of load and car	Size of load (crates)	Test No. 1			Test No. 2			Test No. 3		
		Color of foliage	Decay	Condition	Color of foliage	Decay	Condition	Color of foliage	Decay	Condition
			Per cent			*Per cent*			*Per cent*	
Fourth:										
Car E	350	Very yellow	-----	Wilted	-----	-----	-----	-----	-----	
Car D	350	Yellow	-----	Slightly wilted.	Yellow	2	Wilted	Slight yellowing.	-----	Wilted.
Third:										
Car E	350	Very yellow	-----	Wilted	-----	-----	-----	-----	-----	
Car D	350	Very slight yellowing.	-----	Slightly wilted.	Yellow	1½	Slightly wilted.	Slight yellowing.	-----	Firm.
Car C	336	-----	-----	-----	Slight yellowing.	-----	Firm	Yellow	-----	Do.
Car B	315	Slight yellowing.	-----	Firm	Green	-----	Slightly wilted.	Slight yellowing.	-----	Do.
Car A	294	Yellow	-----	do	do	-----	Firm	Green	4	Do.
Second:										
Car E	350	Slight yellowing.	-----	do	-----	-----	-----	-----	-----	
Car D	350	Green	-----	do	Green	-----	Firm	Green	-----	Do.
Car C	336	-----	-----	-----	do	-----	do	do	-----	Do.
Car B	315	Green	-----	Firm	do	-----	Slightly wilted.	do	-----	Slightly wilted.
Car A	294	Very slight yellowing.	-----	Wilted	do	-----	Firm	do	-----	Firm.
First:										
Car E	350	do	-----	Firm	-----	-----	-----	-----	-----	
Car D	350	Green	-----	do	Green	-----	Firm	Green	-----	Do.
Car C	336	-----	-----	-----	do	-----	do	do	-----	Do.
Car B	315	Green	-----	Firm	do	-----	Slightly wilted.	do	-----	Slightly wilted.
Car A	294	Very slight yellowing.	-----	do	do	-----	Firm	do	-----	Firm.

There was no load of 336 crates in the first test, but in the load of this size on the second trip a slight yellowing was noted, and in the third test the yellowing in the crates in this position was fully developed. The crates in the 350 loads showed degrees of yellowing which varied from a very slight to a full yellow foliage. In the fourth or top layer of the 350-crate loads a more advanced stage of yellowing was found. Car E recorded a very yellow and car D a full yellow condition on the first trip. In the second test a complete and in the final test a slight yellowing was recorded.

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[4] In these tables the first is the bottom layer in all cars. In the 294, 315, and 336 loads the third layer is the top of the load, and in the 350 loads the fourth layer is the top.

Some wilting was noted in the two lower layers, but it was found in considerable quantity in the third layers, particularly of the heavier load, and was general throughout the fourth layer in that position.

Table 9 shows the condition of the celery at the quarter-length position in the cars. Generally speaking, the results are the same as shown in this table and those in Table 8 except for the slightly greater degree of yellowing and wilting in the upper layers of the celery. It will also be noted that this condition of yellowing is very evident throughout three trips and that wilting is slightly more marked in the last test than in the first or second.

TABLE 9.—*Inspection record on arrival at destinations of crates of celery placed at the quarter length of the car in each of three tests, Sanford, Fla., to New York, in 1924*

Layer of load and car	Size of load (crates)	Test No. 1			Test No. 2			Test No. 3		
		Color of foliage	Decay	Condition	Color of foliage	Decay	Condition	Color of foliage	Decay	Condition
			Per cent			*Per cent*			*Per cent*	
Fourth:										
Car E	350	Very yellow	-----	Firm	-----	-----	-----	-----	-----	
Car D	350	Yellow	-----	Wilted	Yellow	-----	Firm	Slight yellowing.	-----	Wilted.
Third:										
Car E	350	do	-----	Firm	-----	-----	-----	-----	-----	
Car D	350	do	-----	Slightly wilted.	Yellow	-----	Slightly wilted.	Green	-----	Do.
Car C	336	-----	-----	-----	Slight yellowing.	-----	Firm	Yellow	11	Do.
Car B	315	Slight yellowing.	-----	Firm	do	-----	Slightly wilted.	Green	3	Slightly wilted.
Car A	294	do	-----	do	Green	-----	Firm	do	-----	Firm.
Second:										
Car E	350	Yellow	-----	do	-----	-----	-----	-----	-----	
Car D	350	Very slight yellowing.	-----	do	Slight yellowing.	-----	Firm	Slight yellowing.	-----	Slightly wilted.
Car C	336	-----	-----	-----	do	1	do	do	2	Do.
Car B	315	Green	-----	Firm	do	-----	Slightly wilted.	do	8	Do.
Car A	294	Slight yellowing.	-----	do	Green	-----	do	Green	-----	Wilted.
First:										
Car E	350	do	-----	do	-----	-----	-----	-----	-----	
Car D	350	Green	-----	do	Green	-----	Slightly wilted.	Green	-----	Firm.
Car C	336	-----	-----	-----	do	-----	Firm	do	3	Wilted.
Car B	315	Green	-----	Firm	do	-----	do	do	6	Slightly wilted.
Car A	294	Very slight yellowing.	-----	Wilted	do	-----	do	do	-----	Firm.

In Table 10 the inspection records are shown for the test crates in the doorway positions in the cars. The same conditions were found in the crates in the quarter-length positions and the same increase in wilting is also apparent. It is also obvious that there is a relation between the height of the load and the condition of the celery. A general study will lead to the conclusion that this average condition of the lighter load is better than that of the heavier load and that the third layer in the 350 load is affected by the placing of a fourth layer upon it, since there are a yellowing and a wilting in the third layer in the 350 loads that are not noticed in the lighter loads. In the 336 load, however, there is a slightly higher degree of yellowing than in the 294 or 315 loads, which is accounted for, perhaps, by the method of loading, which undoubtedly affected the air circulation by obstructing any vertical air movement between the crates.

At the termination of the third test the contents of car A (294 crates) and car D (350 crates) were stacked side by side on the pier. When these two loads were compared a very perceptible yellowing was seen throughout the 350 load, whereas the 294 was green throughout.

TABLE 10.—*Inspection record on arrival at destinations of crates of celery placed at the doorway of the car in each of three tests, Sanford, Fla., to New York, in 1924*

Layer of load and car	Size of load (crates)	Test No. 1			Test No. 2			Test No. 3		
		Color of foliage	Decay	Condition	Color of foliage	Decay	Condition	Color of foliage	Decay	Condition
			Per cent			*Per cent*			*Per cent*	
Fourth:										
Car E	350	Yellow		Firm						
Car D	350	Slight yellowing.		Slightly wilted.	Slight yellowing.		Wilted	Slight yellowing.		Firm.
Third:										
Car E	350	Yellow		Firm						
Car D	350	Slight yellowing.		Slightly wilted.	Slight yellowing.		Wilted	Slight yellowing.		Do.
Car C	336				do		Slightly wilted.	Yellow	16	Wilted.
Car B	315	Green		Firm	do		do	Green		Firm.
Car A	294	Yellow		do	Green		Firm	do		Wilted.
Second:										
Car E	350	Very slight yellowing.		do						
Car D	350	do		Slightly wilted.	Slight yellowing.		Firm	Green		Firm.
Car C	336				do		do	Yellow	4	Slightly wilted.
Car B	315	Green		Firm	do		do	Green		Firm.
Car A	294	Very slight yellowing.		Slightly wilted.	Green		do	do		Wilted.
First:										
Car E	350	Slight yellowing.		Wilted						
Car D	350	Very slight yellowing.		Firm	Slight yellowing.		Firm	Green		Firm.
Car C	336				Green		Slightly wilted.	Yellow	8	Wilted.
Car B	315	Green		Firm	do		do	Green		Firm.
Car A	294	Very slight yellowing.		do	do		do	do		Do.

The preceding tables showing the condition of the celery in the test crates on arrival at destinations relate to the individual crates and the position they occupied in the load. In order to give a more comprehensive idea of the results dealing with color and condition as shown in these tables they are summarized on a percentage basis in Table 11, in which the conditions found in all cars in all tests and in the several layers at different positions in the cars can be readily seen. It is clearly shown that the celery in the bottom layers carried in better condition than that in any other position; also that the proportion of yellowed foliage increases with the height of the load until the fourth layer is reached, where all crates show yellowing.

TABLE 11.—*Color of foliage and condition of celery on arrival at destinations, by layer and position, for all test crates in all cars, Sanford, Fla., to New York, in 1924*

Position of test crates and layer of load	Color of foliage (per cent)					Condition (per cent)		
	Green	Very slight yellow	Slight yellow	Yellow	Very yellow	Firm	Slightly wilted	Wilted
At doorway of car:								
Fourth layer	--------	--------	25.0	8.3	--------	50.0	25.0	25.0
Third layer	33.3	--------	41.6	25.0	--------	50.0	25.0	25.0
Second layer	41.6	25.0	25.0	8.3	--------	66.6	25.0	8.3
First layer	58.3	16.6	16.6	8.3	--------	58.3	25.0	16.6
At quarter length of car:								
Fourth layer	--------	--------	25.0	50.0	25.0	50.0	--------	50.0
Third layer	33.3	--------	33.3	33.3	--------	50.0	33.3	16.6
Second layer	25.0	8.3	58.3	8.3	--------	50.0	41.6	8.3
First layer	83.3	8.3	8.3	--------	--------	66.6	16.6	16.6
At bunker of car:								
Fourth layer	--------	--------	25.0	50.0	25.0	--------	25.0	75.0
Third layer	25.0	8.3	33.3	25.0	8.3	66.6	25.0	8.3
Second layer	83.3	8.3	8.3	--------	--------	75.0	16.6	8.3
First layer	83.3	16.6	--------	--------	--------	83.3	16.6	--------

To illustrate more clearly the effect of placing an additional layer on the third layer in the car, a comparison on a percentage basis is made in Table 12 between the conditions in the third layers of the loads containing less than 350 crates and those in the third layer in the 350-crate loads. A study of this table shows that the placing of an additional layer has an effect on the coloring of the foliage in the layer beneath it. This is very noticeable at the doorway and bunker positions, where no green color is found in the third layer of the 350 load, when compared with the 37.5 and 50 per cent in the lighter loads at these positions. There is also a difference in the condition of the celery when its firmness or wilting is taken into consideration, but this difference is not so marked as in the coloring. In all probability this yellowing is caused by the shutting off of the air circulation over the top of the third layer, which is also responsible for creating the higher temperature of the crates in this position in the car. The temperature curves already discussed clearly demonstrate this point.

TABLE 12.—*Color of foliage and condition of celery on arrival at destinations in the third layer of the loads of 350 crates compared with that in the third or top layer of the loads containing less than 350 crates*

Position of test crates in the third layer of different loads	Color of foliage (per cent)					Condition (per cent)		
	Green	Very slight yellow	Slight yellow	Yellow	Very yellow	Firm	Slightly wilted	Wilted
At doorway of car:								
350-crate load	--------	--------	75.0	25.0	--------	50.0	25.0	25.0
Less than 350 load	50.0	--------	25.0	25.0	--------	50.0	25.0	25.0
At quarter length of car:								
350-crate load	25.0	--------	--------	75.0	--------	25.0	50.0	25.0
Less than 350 load	37.5	--------	50.0	12.5	--------	62.5	25.0	12.5
At bunker of car:								
350-crate load	--------	25.0	25.0	25.0	25.0	50.0	50.0	25.0
Less than 350 load	37.5	--------	37.5	25.0	--------	87.5	12.5	--------

ICE CONSUMPTION

Inasmuch as a study of the performance of these refrigerator cars under varying weather conditions has shown a similarity of temperature in like loads throughout the series of tests, the quantities of ice used may be considered as an index of their efficiency. The icing records, Tables 3, 5, and 7, show how much ice was supplied to all cars on all trips. Table 13 shows the total and average quantities for all cars except car C, which on arrival at New York was not unloaded but was sent to Providence, R. I. It was reiced at Greenville, N. J., with 1,200 pounds, as will be seen by referring to Table 7, the record for the third test. Since that car received an additional icing and all the other cars terminated their journey at New York, the last icing of this car will not be considered, and its trip will be treated as terminated at New York so far as these tests are concerned. The total and average weights of ice supplied cars A and D are identical, but car A showed a lower temperature and as a result carried its load in better condition than car D, indicating the effect of a large load on the efficiency of this type of car. Car B used only an average of 584 pounds less than car A. Although this quantity may seem large, in actual practice it is not excessive, being approximately equivalent to two common-sized cakes of ice.

Since car E was used only in the first trip and compared with car D with its 350-crate load in that trip only, the details of ice supplied to car E are not shown in Table 13, but by referring to Table 3 it will be seen that the total ice supplied to both cars D and E was exactly the same, although the quantity supplied at different icing stations varied.

Table 13.—*Total and average ice consumption of four refrigerator cars loaded with celery used in three tests, Sanford, Fla., to New York, in 1924*

Test	Ice supplied (pounds)				
	Car A	Car B	Car C	Car D	Car E
No. 1	18,200	16,100	----------	18,600	18,600
No. 2	15,350	14,500	14,500	14,950	----------
No. 3	14,900	16,100	15,000	14,900	----------
Total	48,450	46,700	29,500	48,450	----------
Average	16,150	15,566	14,750	16,150	----------

The temperature and condition of the celery in car B, with its load of 315 crates, may be favorably compared with those in car A, with the 294 load, in spite of the fact that it consumed slightly less ice than car A. Car C, however, used 1,400 pounds less than car A. The temperature record shows that this car did not have as good refrigeration as car A, which was probably because of the lack of air circulation brought about by the manner of loading. Refrigeration can not take place without melting ice, and melting is helped by the circulation of the air within the car over and through the spaces between the ice in the bunkers.

SUMMARY

Prior to 1918 no attempt was made to standardize refrigerator-car equipment.

Recommendations and specifications were issued in 1918 by the United States Railroad Administration for the "United States standard refrigerator car."

The fundamental requirement of a refrigerator car is that it shall deliver its load at destination in a condition as nearly as possible the same as that in which it was received.

A refrigerator car about 3 feet shorter than the recommended standard specification has been supplied to shippers, who believe that it will not carry its load.

The cooling of a refrigerated shipment is dependent upon the circulation of air within the car. Air circulation within a car is slow, even when the best of conditions are provided.

Loading which allows no continuous channels through which air can move without interruption retards or destroys refrigeration.

It has long been recognized that when too great a bulk is placed in a refrigerator car there is danger of deterioration of the load in its top layers.

The general opinion of shippers and receivers is that 294 crates of celery are all that the short car described can carry with safety.

Three test trips were run to determine the efficiency of this short car. These tests showed:

A very heavy load detracts from the efficiency of the car.

This type of car will effectively refrigerate a load of 294 or 315 crates of celery.

A load of 336 crates loaded 8 crates wide and 3 layers high in 14 stacks retards the air circulation within the car, thus preventing efficient refrigeration of the load.

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August 14, 1925

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